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Soil Quality and Heavy Metal Concentrations in Agricultural Lands around Dyeing, Glass and Textile Industries in Tangail District of Bangladesh

T. R. Tusher*, A. S. Piash, M. A. Latif, M. H. Kabir and M. M. Rana

Department of Environmental Science and Resource Management
Mawlana Bhashani Science and Technology University, Tangail-1902
*Corresponding author: trtusher.esrm@gmail.com

Abstract
The study was conducted to investigate the soil quality including heavy metal concentrations in agricultural lands around dyeing, glass and textile industries at Tangail district of Bangladesh. A total of nine samples, three samples from each industrial site, were collected at a depth of 0-15 cm with an interval of 10 m from each point of the agricultural lands adjacent to selected industries for analyzing the soil chemical properties such as pH, OM, total N, available P and S including heavy metals (Pb, Cd, Ni, Cu and Cr) concentrations. The study found soil pH of 6.4 and 6.1 around textile and glass industry, respectively, while comparatively lower pH (4.4) was observed around dyeing industry. Comparatively higher levels of OM, total N, available P and S were found in soil around dyeing industry, whereas lower levels of OM and available S were observed around textile industry. The Cu, Pb and Cr were the dominant heavy metal around dyeing, glass and textile industry, respectively.

Keywords: Dyeing industry, Glass industry, Heavy metals, Soil properties, Textile industry

Introduction

Soils of the world have been degraded and contaminated by various anthropogenic activities that change the physical, chemical and biological properties of soil; resulting in nutrient deficiency, soil toxicity, improper soil and crop management, alteration of agricultural landsand also human and animal health hazard through the food chain (Tu *et al.*, 2000; Dahmani-Mueller *et al.,* 2001; McGrath *et al.,* 2002; Rahman *et al.,* 2012; Adegoke, 2009). Industrial discharge of untreated or partially treated effluents directly into surrounding agricultural lands is considered as the most significant anthropogenic activity responsible for soil pollution by various pollutants like heavy metals such as Cd, Cu, Zn, Cr, Ni, Pb and Mn (Islam *et al.*, 2012; Jolly *et al.*, 2012; Yadav *et al.,* 2002). Agricultural crops can also be injured, ranged from visible markings on the foliage to premature death of the plants, when exposed to high concentrations of pollutants (Gheorghe and Ion, 2012).

Bangladesh has now more than 30,000 industrial units of which about 900 are large polluting industries, which discharging heavily toxic effluents directly into the adjacent soils (Nuruzzaman *et al.*, 1998). Approximately 30 million gallons of untreated industrial waste water effluent are mixing daily with our environment mainly with water and soil (Jolly *et al.*, 2012). Among them, around 600-700 textile, dyeing and glass industries have been set up around Dhaka at Narayangonj, Tejgaon, Savar, Tongi, Gazipur and Tangail areas during the last few years (Khan, 2006). The contamination by heavy metals causes a serious problem and threaten to human health and problems associated with long-term heavy metal exposures causes eventually death (Rahman *et al.,* 2012).

There are 1184 industries in Tangail from which a large amount of industrial effluents are discharged into the surrounding agricultural lands daily (BBS, 2013). As a result, the agricultural lands are losing their fertility and the crop production is decreasing. The soil quality along with the heavy metal concentrations in these agricultural lands exposed to different industrial effluents is needed to investigate to understand the extent of effects of industrial effluents of each category on agricultural soils. With this incentives the study was conducted: (i) to assess the soil properties (pH, OM, total N, available P and available S) including heavy metals (Pb, Cd, Ni, Cu, Cr) of agricultural lands adjacent to the dyeing, glass and textile industries in Tangail district; and (ii) to identify the dominant heavy metals in soil around dying, glass and textile industries.

Materials and Methods

Study area

The study area was Tangail sadar and Mirzapur Upazilla of Tangail district which is surrounded by several districts, such as Jamalpur on the north, Dhaka and Manikganj on the south, Mymensingh and Gazipur on the east, and Sirajganj on the west. The total geographic area of the district is 3414.35 km^2 and the district lies between 24°01′00" and 24°47′00"N north latitudes and between 89°44′00" and 90°18′00" east longitudes (BBS, 2013).

Sample collection and preparation

A total of nine (9) samples, three from each industrial site, were collected at a distance of 10 m from each point of the agricultural land in the vicinity of three different industries (Alauddin Textile Mills, Tangail; Newtex Dyeing industry, Mirzapur; Nasir Group Glass Industry, Mirzapur). The soil samples were collected at 0-15 cm depth. The details of the soil samples collection are described in Table 1. The collected soil samples were carried to the laboratory of the Department of Environmental Science and Resource Management (ESRM), Mawlana Bhashani Science and Technology University (MBSTU), Tangail, Bangladesh, where the samples were dried in air for 10 days by spreading on a clean piece of paper, and then gravels, pebbles, plant roots, leaves, etc. were picked up and removed. The samples were then mixed well and grind to pass through a 2 mm mesh stainless steel sieve. The soil samples were kept in a clean polythene bag and then transported to the laboratory of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh for the analysis of soil properties including heavy metals.

Table 1. Details of soil samples with their sampling points and locations

SL No.	Sample code	Sampling distance (m)	Name of the industry
1	DS1	0	
2	DS2	10	Newtex Dyeing Industry
3	DS3	20	
4	GS1	0	
5	GS2	10	Nasir Glass Industry
6	GS3	20	
7	TS1	0	
8	TS2	10	Alauddin Textile Mills
9	TS3	20	

Sample analysis

The chemical properties of soil were analyzed by different methods such as soil pH by digital pH meter (Model: ZD5PM0909), organic matter (OM) by Walkley and Blackôs wet oxidation method (Piper, 1950), total nitrogen (N) by Semi-micro Kjeldahl method (Page *et al.*, 1989), available sulphur (S) by Turbidimetric method (Jackson, 1973), available phosphorus (P) by Olsenôs method (Black, 1965) and the heavy metals lead (Pb), cadmium (Cd), nickel (Ni), copper (Cu) and chromium (Cr) were analyzed by using Atomic Absorption Spectrophotometer (McLaren *et al.*, 1984).

Heavy metal contamination assessment

The contamination factor (CF) is the ratio obtained by dividing the measured concentration of individual metal in the soil by the background value given by Turekian and Wedepohl (1961) and the CF for single metal was calculated by the following formula (Tomilson *et al.*, 1980):

$$CF = \text{Measured metal concentration } (C_m) / \text{ Background concentration of the metal } (B_m)$$

The contamination degree (CD) for each point was calculated as sum of all CF (Ahdy and Khaled, 2009). Hakanson (1980) demonstrated 4 grade ratings of soil in relation to CF values such as low (CF <1), moderate (1 Ò CF <3), considerable (3 Ò CF <6), and very high (CF Ó 6). Moreover, Tomilson *et al.* (1980) stated 4 classes of soil depend on the CD levels, such as CD <6(low), 6 Ò CD <12(moderate), 12 Ò CD <24(considerable), and CD Ó 24(very high).

Statistical analysis

The data were finally compiled, tabulated and subjected to statistical analysis. The Microsoft Office Excel 2013 software were used for data analysis and presentation. Various descriptive statistical measures such as range, mean and standard deviation (SD) were used.

Results and Discussions

Soil pH

The result of the study found that soil pH was ranged from 4.0 to 4.8 with mean value of 4.4 in the vicinity of dyeing industry, whereas soil pH was ranged from 5.8 to 6.4 with average value of 6.1, and from 6.0 to 7.0 with the mean value 6.4 around the glass and textile industry, respectively (Table 2). The soil pH observed around glass and textile industries were within the standard value 5.5 to 7.3 by BARC (1997), while the samples around dyeing industry showed lower value from standard value. The highest pH (7.0) was found at TS2 around textile industry and the lowest (4.3) was at DS3 around dyeing industry (Table 2). Very strongly acidic soil pH (<4.5) was observed around dyeing industry, while slightly acidic (5.6 to 6.5) was found around both glass and textile industries. The value of pH decreases with the decrease of carbonate and bicarbonate (Sonawane *et al.,* 2010) which might be the cause behind the very strong acidic soil pH around the dyeing industry. Shivkumar *et al.* (2012) reported that the pH range of all the soil samples in all the industrial area were in the normal range of from 6.2 to 7.9 in Mysore city of India.

Table 2. Observed soil properties of agricultural lands around different industries

SL No.	Sample ID	Soil pH	OM (%)	Total N (%)	Available P (ppm)	Available S (ppm)
1	DS1	4.3	5.52	0.33	39.09	620.63
2	DS2	4.8	4.95	0.40	46.60	1993.95
3	DS3	4.0	8.87	0.58	38.01	1941.13
Mean ± SD		**4.40 ± 0.40**	**6.45 ± 2.12**	**0.44 ± 0.13**	**41.23 ± 4.68**	**1518.57 ± 778.09**
4	GS1	6.2	4.80	0.07	20.75	122.80
5	GS2	6.4	4.45	0.09	19.41	228.50
6	GS3	5.8	4.31	0.12	24.26	215.24
Mean ± SD		**6.10 ± 0.31**	**4.52 ± 0.25**	**0.10 ± 0.03**	**21.47 ± 2.50**	**118.83 ± 57.56**
7	TS1	6.0	2.10	0.16	36.12	125.45
8	TS2	7.0	0.91	0.07	28.84	67.35
9	TS3	6.2	0.91	0.08	25.07	68.67
Mean ± SD		**6.40±0.53**	**1.31±0.69**	**0.10±0.05**	**30.01±5.62**	**87.16±33.17**

Note: DS- Dyeing industry sample, GS- Glass industry sample, TS- Textile industry sample

Organic matter (OM)

The OM content in soil was ranged from 4.95 to 8.87% around the dyeing industry, whereas 4.31 to 4.80 and 0.91 to 2.10 % were observed around the textile and glass industry, respectively. The mean OM content was 6.45, 4.52 and 1.31% in soil around the dyeing, textile and glass industry, respectively. The highest OM content (8.87%) was recorded at DS3 and the lowest (0.91%) was at the sampling points TS2 and TS3 (Table 2). It was also observed that in case of glass and textile industries the OM content in soil decreases with increase of the distance from the industry. In case of dying industry, the irregular values are observed because effluent discharge to the agricultural land from all sides through the leakage of pipeline. The values of OM in soil around glass industry were within the standard value 3.00 to 5.00 % set by BARC (1997), while the soil OM around dyeing and textile was found above and below the standard value. Kanta *et al.* (2014) stated that the high range of OM from 0.31 to 12% in agricultural land of the Tongi industrial areas, Gazipur due to heavy organic load in the river. Strongly acidic condition in the soil is the main reason for high amount of OM because of low growth of microorganism which results in low oxidation of organic matter (Biswas and Mukherjee, 1997). Thus, it might also be the main reason of high OM content in agricultural land around dyeing industry.

Total nitrogen (N)

The study observed that the total N content in soil was ranged from 0.33 to 0.58 % with mean value of 0.44 in the vicinity of dyeing industry, whereas the total N content was ranged from 0.07 to 0.12 % with average value of 0.01 and from 0.08 to 0.16 % with the mean value of 0.10 % around the glass and textile industry, respectively. The highest content of total N was found at the point DS3 and the lowest content was found in GS1 and TS2. The mean value of total N content found in soil around dyeing industry exceeded the standard value 0.32 % by BARC (1997), while lower value from the standard was observed in case of glass and textile industries. Ayres and Westcot (1994) stated that total N is a necessary primary macronutrient for plants that stimulates plant growth and is usually added as a fertilizer but can also be found in wastewater as nitrate, ammonia, organic nitrogen or nitrite. The total N content recorded at different sampling points around different industries of Tangail district was ranged from 0.074 to 0.583 % which was similar to the total N contents of Gazipur sadar thana soils ranged from 0.03 to 0.47% (SRDI, 2001).

Available phosphorus (P)

The study revealed that the available P content was observed 38.1 to 46.6 ppm with mean value of 42.53 ppm around the dying industry, whereas the range proximity to glass and dying industries were 19.41 to 24.26 and 24.07 to 36.12 ppm with mean value of 21.47 and 29.68 ppm, respectively. The highest value was found at DS2 and lowest value was recorded at GS2 point (Table 2). The observed mean available P contents around the dyeing and textile industries were above the standard value 26.25 ppm of BARC (1997), while the lower value was recorded in soil around glass industry. Kanan *et al.* (2014) found that the concentration of available P was 29.84 to 30.70 ppm in the soil around the textile industry in Narsingdi which was similar to the present study. Soil irrigated with waste water contains high amount of available P which play significant role in plant growth (Nidhi *et al.*, 2011; Joshi and Santani, 2012).

Available sulphur (S)

The study revealed that level of available S ranged from 620.63 to 1993.95 ppm with mean value of 1515.75 near to the dyeing industry whereas it ranged from 122.8 to 228.5 ppm with mean value of 118.83 adjacent to the glass industry and 67.35 to 125.45 ppm with mean value of 87.16 in the soil proximity to the textile industry. The highest content of available S was found at the point of DS2 and lowest was found at the point of TS2 (Table 2). The value of available S concentration in all sampling points exceeded the permissible value 26.25 ppm given by BARC (1997). Strong acidic condition in soil support poor growth of microorganism. As a result, low decomposition of sulpher is responsible for high concentration of sulpher (Biswas and Mukherjee, 1997; Soni and Bhaskar, 2012). This might be the main reason of high concentration of sulpher in the soil adjacent to dyeing industry.

Lead (Pb)

The concentration of Pb was found 24.55 to 42.4 ppm in soil around the dying industry with mean value of 32.5 ppm, whereas the concentration ranged from 96.5 to 167.1 and 28.2 to 29.2 ppm around the glass and textile industry with mean value of 134.9 and 27.18 ppm, respectively. The highest concentration of Pb was found at GS2 and the lowest concentration was observed at TS1 (Table 3). All the values exceeded the maximum permissible level of Pb (0.1 ppm) in soil (Chiroma *et al.*, 2014) due to continuous discharge of effluents on the surrounding lands. Vandana *et al.*(2011) observed the concentration of Pb ranging from 42.9 to 1835.0 ppm in hazardous waste disposal site of Hyaderabad, India. Lead is used in fluxes and coloring agents in the glass industry (IFC, 2007). Uses of huge amount of Pb as coloring agent might be the cause of higher concentration of Pb in soil around the glass industry.

Cadmium (Cd)

The study investigated that the total Cd concentrations were ranging from 0.55 to 1.00 ppm around dyeing industry with mean value of 0.83 ppm, whereas 1.45 to 1.60 ppm with mean value of 1.53 ppm and 0.75 to 2.70 ppm with mean value of 1.4 ppm was observed in soil around the glass and textile industry, respectively. The highest value was found at TS1 and the lowest value was found at TS1 and TS3 (Table 3). The study indicated that the all the values of Cd concentration exceeded the maximum permissible level of 0.01 ppm in soil (Chiroma *et al.*, 2014). Bharti *et al.* (2013) recorded that the mean concentration of Cd was 1.927 ppm in the soil irrigated with effluent of textile in Panipath city of India. In the study, the concentration of Cd was found low in comparison with other heavy metals because of low adsorptive nature of soil (Mido and Satake, 2003).

Nickel (Ni)

The investigation revealed that concentration of Ni ranged from 32.65 to 50.20 ppm with mean value of 42.73 in agricultural soil adjacent to the dyeing industry whereas level was found 46.00 to 58.05 ppm with mean value of 52.56 near to the glass industry and 37.00 to 41.75 ppm was found near the textile industry. The highest concentration was found at GS1 and lowest was found at TS1 (Table 3) and the value of all points exceeded the standard limit 6.5 (Chiroma *et al.*, 2014). Iqbal *et al.* (2011) observed the concentration of Ni ranging from 32.1 to 94 ppm in the agricultural land irrigated with industrial effluent in Pakistan. Kanta *et al.* (2014) observed the concentration of Ni ranging from 11.11 to 80.82 ppm in agro industrial area of northern part of Dhaka. Ni is used as mold alloy because of good abrasive resistance and good corrosion resistance at high temperatures in glass industry (Hoganas, 2013). That is the reason for highest concentration of Ni near glass industry.

Copper (Cu)

The study showed that the concentrations of copper (Cu) were recorded ranging from 103.70 to 151.75 ppm in dyeing industry, 29.05 to 43.80 ppm in glass industry and 29.55 to 79.55 ppm in textile industry soils. The mean value of total Cu concentration was found 122.97, 35.93 and 47.62 ppm around dyeing, glass and textile industry, respectively. The highest value of Cu was found at DS3 and the lowest value was observed at GS2 (Table 3). All the values of Cu concentrations exceeded the maximum permissible level of Cu (1.5 ppm) in soil (Chiroma *et al.*, 2014). As industrial effluents contain significant amounts of Cu (Sharma and Raju, 2013) the continuous discharge of Cu containing industrial effluents might be the cause of the higher Cu concentrations in soil of surrounding agricultural lands. The average value of Cu in soil around the glass and textile industry was similar to the results reported by Zakir *et al.*(2015) in industrial areas.

Chromium (Cr)

The study revealed that the concentration of Cr ranging from 48.5 to 86.8 ppm in the soil adjacent to the dying industry with mean value of 69.27 ppm, whereas the concentration was found 65.65 to 166.05 ppm around the glass industry with mean value of 122.38 ppm and 44.55 to 67.65 ppm with mean value of 58.68 ppm around the textile industry. The highest concentration of Cr was recorded at GS3 and lowest concentration was recorded at TS1 (Table 3). All the values of Cr concentrations exceeded the maximum permissible level of Cr (0.05) in soil (Chiroma *et al.*, 2014). ElBahi *et al.* (2013) observed the concentration of Cr in the soil of Wadi El Rayan, Egypt ranging from 23-203 ppm. The Cr is used as green coloring agent in form of Sodium dichromate ($Na_2Cr_2O_7$) in fluxing and production of frit (Agarwal and Varshney, 2014; IFC, 2007) which is responsible for high concentration of Cr surrounding the soil of glass industry.

Table 3. Heavy metal concentrations in agricultural lands around different industries

SL No.	Sample ID	Pb (ppm)	Cd (ppm)	Ni (ppm)	Cu (ppm)	Cr (ppm)
1	DS1	24.55	0.55	32.65	113.40	48.05
2	DS2	30.55	0.95	45.35	103.70	72.95
3	DS3	42.40	1.00	50.20	151.75	86.80
Mean ± SD		**32.5 ± 9.08**	**0.83 ±0.25**	**42.73±9.06**	**122.95±25.1**	**69.27±19.64**
4	GS1	96.50	1.45	58.05	43.80	65.65
5	GS2	167.10	1.55	46.00	29.05	135.45
6	GS3	141.10	1.60	53.65	34.95	166.05
Mean ± SD		**134.9±35.1**	**1.53±0.08**	**52.56±6.09**	**35.93±7.42**	**122.38±51.46**
7	TS1	28.20	2.70	28.20	36.12	44.55
8	TS2	24.15	0.75	37.00	28.84	63.85
9	TS3	29.20	0.75	41.75	25.07	67.65
Mean ± SD		**27.18±2.67**	**1.4±1.13**	**35.65±6.88**	**30.01±6.88**	**58.68±12.39**

Note: DS- Dyeing industry sample, GS- Glass industry sample, TS- Textile industry sample

Soil contamination assessment

The highest CF value was found 9.0000 for Cd at TS1 among the all studied heavy metals might be due to the discharged of textile waste water in this site whereas the lowest CF value was found 0.5571 in TS3 point. The mean CF values of all metals were found in the following order: Cd (4.1851: considerable) >Pb (3.2375: considerable) > Cu (1.3991: moderate) > Cr (0.9271: low) > Ni (0.6418: low) and the study stated that soil of the studied industrial areas were low to considerably contaminated by heavy metals (Table 4). The maximum CD value was found 16.3485 at GS2 whereas the minimum CD (5.6018) was found at TS2. The CD values for all metals in the all points over the all sites were found higher than 6 to lower than 24 which indicated moderate to considerable level of contamination apart from the TS2 and 3, might be due to the receiving of extensive amount of municipal and industrial waste water in the study areas (Table 4).

Table 4. Contamination factor (CF) and contamination degree (CD) of heavy metals for soil in the study area

Site	Points	Contamination Factor (CF)					CD
		Pb	Cd	Ni	Cu	Cr	
Newtex Dyeing Industry	DS1	1.23	1.83	0.48	2.52	0.53	6.59
	DS2	1.53	3.17	0.67	2.30	0.81	8.48
	DS3	2.12	3.33	0.74	3.37	0.96	10.53
Nasir Glass Industry	GS1	4.83	4.83	0.85	0.97	0.73	12.21
	GS2	8.36	5.17	0.68	0.65	1.51	16.35
	GS3	7.01	5.33	0.79	0.78	1.85	15.75
Alauddin Textile Mills	TS1	1.41	9.00	0.41	0.80	0.50	12.12
	TS2	1.21	2.50	0.54	0.64	0.71	5.60
	TS3	1.46	2.50	0.61	0.56	0.75	5.88
Minimum (M_{min})		1.21	1.83	0.41	0.56	0.50	5.60
Maximum (M_{max})		8.36	9.00	0.85	3.37	1.85	16.35
Mean		3.24	4.18	0.64	1.40	0.93	10.39

Conclusion

The study observed that very strong acidic soil and highest OM, total N, available P and S were found around dyeing industry whereas the lowest OM, N and S were found around the textile industry, and the P around the glass industry. The Cu, Pb and Cr were the dominant heavy metal found in soil around dyeing, glass and textile industry, respectively, and the study showed that the concentration of Cd was low in all the industrial area. The CD value indicated that low to consideration level of soil contamination by heavy metals. Therefore, to maintain the soil quality and reduce the heavy metal pollution in the study area the listed measures are needed to be taken: (i) Industrial units must install and regularly operate Effluent Treatment Plant (ETP); (ii) Industries should maintain the standard level mentioned on Guide for Assessment of Effluent Treatment Plant, 2008 before discharging of effluents; (iii) Environment Conservation Act, 1995 should be imposed strictly and proper monitoring should be conducted by the Government authority.

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